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3. In a race of Paramecium which upon extended examination shows no hereditary abnormalities, conjugation results in the appearance of many lines which are hereditarily abnormal, others which are normal throughout.

4. In the diverse lines descended from the separate exconjugants of a conjugating culture, the two lines descended from the two individuals that have conjugated together tend to be alike in respect to normality or abnormality. That is, if the progeny of the exconjugant *a* are abnormal, the progeny of its mate *b* are more frequently abnormal than would be the case if the distribution of abnormal races were not affected by conjugation.

Our main result, therefore, is that in respect to these abnormalities, while some lines are constant in hereditary character, in others hereditable variations do occur within the line, so that by selection it is possible to break the single stock into a number of stocks differing hereditarily. The genotype in these cases therefore does not remain constant in uniparental reproduction. The condition on which evolution through selection depends is therefore realized in respect to these characters.

The complete paper of which this a summary appears in the *Journal of Experimental Zoölogy.*

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[1] Calkins, G. N., and Gregory, L. H., Variations in the Progeny of a Single Exconjugant of Paramecium Caudatum, *J. Exp. Zoöl.*, 15, 467–525 (1913).

THE INFLUENCE OF THE MARGINAL SENSE ORGANS ON FUNCTIONAL ACTIVITY IN *CASSIOPEA XAMACHANA*

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Presented to the Academy, October 27, 1915

1. *The Influence of the Sense Organs on the Rate of Regeneration.* The conclusion of many of the earlier workers on the problems of regeneration that the nervous system had an important part to play in the processes of regeneration has been attacked by most of the more recent students of these problems. While Bardeen ('01), Herbst ('96), Goldstein ('04), Wolff ('95, '02) and others maintained that there was some direct influence of the nervous system, or some portion of it (sensory ganglia Herbst), and Child ('04) recognized the indirect influence of the nervous system, exhibited through muscular activity; Goldfarb ('09), Stockard ('09) *et al* have denied that there is even an indirect influence of the nervous system.

An especially favorable opportunity for studying this problem is afforded by the Rhizostomous medusa *Cassiopea xamachana* the disks of which can be separated from the oral arms and kept in dishes of sea water for an indefinite period. Such disks retain their capacity for regeneration, while on account of their shape and the location of the marginal sense-organs they permit of many types of operation which are possible only on some simple organism.

In order to determine the influence of the nervous system on the rate of regeneration the following experiments were carried out. Pairs of entire disks of the same size were compared from one of which all of the rhopalia were removed while from the other an equal amount of tissue was removed from the bell margin between the rhopalia. In these, as in all of the following experiments, the amount of regeneration was measured inward from the edge of a hole in the center of the disk from which a circular piece of tissue had been removed.

The active member of any pair of such disks, being compared, regenerated faster in 75% of the experiments. In 10% of the experiments the two disks regenerated at an equal rate, while in the remaining 15% the inactive member of the pair showed the higher rate of regeneration, thus confirming the observations of Zeleny ('07) and Stockard ('09) that under such conditions sometimes the active and sometimes the inactive member of any pair of disks regenerates faster.

The marked divergency among the results of this series of experiments indicated that there must be individual physiological differences among the medusa disks of sufficient amount to invalidate the conclusions drawn from the comparison of entire disks. In all of the later experiments, therefore, the two halves of *one and the same disk* were compared with one another. This comparison is made possible through the fact that in *Cassiopea* the muscles and nerve fibres are confined to the subumbrella surface of the disk so that when two narrow strips of the subumbrella ectoderm, on opposite sides of the disk, are removed the two halves are insulated from one another until a new layer of tissue containing nerve fibres has been regenerated over one of the denuded areas. About thirty-six hours would elapse before functional nerve fibres would be regenerated, so by scraping over the strips each day the insulation of the halves of a disk was readily maintained.

In the second type of experiments the two halves of a disk were insulated in the manner just described; the sense-organs were removed from one half while an equal amount of tissue was removed from between the sense-organs of the other half. The disks were then allowed to regenerate in jars of normal sea water, the insulation between the halves being maintained throughout the experiment. The physiological characteristics of the two halves of any disk would at the start of an experiment be identical, and the pulsations of the half on which the rhopalia remained were sufficiently strong to move the inactive half about in the water and thus reduce to a very small amount any difference in aëration.

In every instance where the rates of regeneration of the two halves of a medusa disk under these experimental conditions were compared it was found that the active half—*i.e.*, the half on which the rhopalia remained—regenerated at a more rapid rate than the inactive half. The results of two such series of experiments in which the insulated halves of 40 disks were compared are shown in curves *A* and *B*, figure 1.

The proportion between the amounts of tissue regenerated each day, when that from the inactive half is taken as the unit was respectively: first day, 1 : 1.53; second day, 1 : 1.44; third day, 1 : 1.41; fourth day, 1 : 1.38; and for the fifth day, 1 : 1.39.

Although the results from the experiments just described show conclusively that each half-disk on which the sense-organs were present regenerated faster than its companion half-disk without sense-organs, no evidence was afforded respecting the nature of the influencing factors. Since the muscular activity was the most striking difference between the two half-disks in this type of experiment other operations were undertaken to eliminate this factor. When disks with insulated active and inactive halves are put into a solution made up of 85 parts sea water and 15 parts 0.6 *m* $MgSO_4$ the activity first of the muscles, then of the rhopalia, and finally of the conducting portion of the nervous system is entirely suppressed. Under these experimental conditions the rate of regeneration of both half-disks becomes very much lowered. For the first few hours the half-disk on which the rhopalia remain regenerates faster, but after the full effect of the magnesium has become established the rate is the same for both halves.

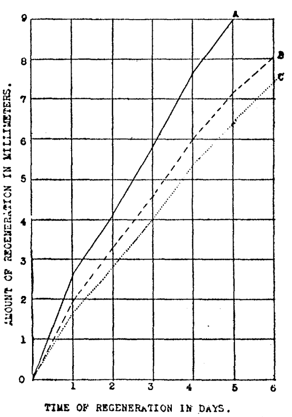

FIG. 1.—COMPARATIVE RATES OF REGENERATION OF SPECIMENS IN SEA WATER. *A*. HALF-DISKS WITH SENSE ORGANS ATTACHED. *B*. HALF-DISKS ACTIVATED WITH CIRCUIT WAVE OF CONTRACTION. *C*. HALF-DISKS WITHOUT SENSE ORGANS (INACTIVE).

As shown in the curves in figure 2 which represents the results of the comparison of the halves of 40 disks the difference in rate of regeneration is apparent only during the period before the rhopalia had come completely under the influence of the anesthetic.

These results, while confirming the previous observations that a half-disk under the control of the rhopalia regenerates faster than its companion half-disk from which these organs have been removed, were not sufficient, because of a lack of knowledge of the differential action of the magnesium ions on the several tissues involved, to determine whether the factor of muscular activity was or was not concerned in the initial difference in rate of regeneration. Fortunately another type of operation made known by Mayer ('06) makes it possible to determine the influence of muscular activity in a half-disk from which the rhopalia have been removed. When a series of cuts are made in the subumbrella tissues of a half-disk in such a manner that an endless labyrinth of tissue is formed, an entrapped wave of contraction can be initiated by an induction shock. This contraction wave will traverse the labyrinth of tissue for days before the muscles are overcome by fatigue so that the regeneration of new tissue to fill the open center of the disk will be completed before the contractions cease.

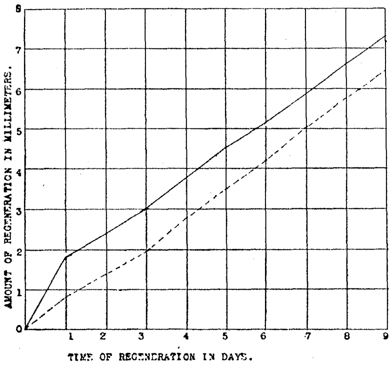

FIG. 2.—COMPARATIVE RATES OF REGENERATION OF SPECIMENS IN MAGNESIUM SOLUTION. SOLID LINE HALF-DISKS WITH SENSE ORGANS ATTACHED. BROKEN LINE HALF-DISKS WITHOUT SENSE ORGANS.

When the two insulated halves of a disk, from which all of the rhopalia have been removed while in the subumbrella tissues of one of them a circuit wave of contraction is maintained, are compared the actively contracting half-disk shows a slightly higher rate of regeneration than the inactive half. The difference in the rapidity of regeneration of the two halves in these experiments, as is shown by comparing curves *B* and *C*, figure 1, is not nearly as great as when a half-disk without rhopalia is compared with one on which the rhopalia remain (curves *A* and *C*, figure 1). When the fact that the rate of pulsation of a half-disk contracting under the influence of an entrapped wave is on the average more than three times the normal rate for a disk of the same size is taken into account it is at once apparent that some factor other than muscular activity must be the most important influence in determining the rate of regeneration. Added confirmation of this conclusion is obtained when the rates of regeneration of two insulated half-disks are compared, one of which is contracting normally under the influence of its rhopalia while an entrapped wave of contraction is maintained in the subumbrella tissues of the other (curves *A* and *B*, figure 1). In experiments of this type the rate of regeneration is throughout its course about 1.3 times greater for the half-disk on which the rhopalia remain than for the half of which the muscles are contracting under the influence of a circuit wave of contraction. In terms of muscular activity the last mentioned half-disk is developing more than three times the energy of the former but its rate of regeneration still remains lower than that of the half-disk under the control of the rhopalia. It is quite apparent, therefore, that there is no direct relationship beween the extent of muscular activity and the rate of regeneration, but that some other factor directly related to and controlled by the marginal sense-organs plays the most important part in determining the rate of regeneration. In the absence of the influence of the sense-organs regeneration can take place in an apparently normal manner, but always at a decidedly lower rate than that shown by a specimen under the control of the sense-organs.

2. *Influence of the Sense-Organs of Cassiopea on the Rate of Metabolism as Measured by Production of Carbon Dioxide.* The striking evidence of some sort of influence exerted by the rhopalia on the rate of regeneration in *Cassiopea,* as described above, naturally raises the question as to whether or not a similar influence on other activities not included in the former experiments can be detected. Since a measure of general metal bolic activity may be obtained by determining the relative rates of CO_2 production of different animals under various sets of experimenta-conditions a series of determinations of total metabolic activity of half-disks of *Cassiopea* under conditions similar to those characterizing the regeneration experiments were carried out. To accomplish this end the disks were separated into halves, the appropriate operations performed, and each one put into a separate jar containing 1000 cc. of sea water. The jars were then tightly closed by a rubber gasket and a clamped top, and, after a given interval of time, the relative amount of CO_2 produced was measured by titrating against normal sea water taken as a control at the time the jars were filled.

When a half-disk with its sense-organs was compared with the other half of the same disk from which the sense-organs had been removed the amount of CO_2 produced was always found to be greater for the normal half-disk. This result is parallel to that obtained from the comparison of the rates of regeneration and may be, at least in part, explained by the activity of the muscular system in the half-disk with sense-organs. When a comparison of the rates of metabolism is made between the halves of a disk from which all its sense-organs have been removed while the muscular system of one-half is contracting under the influence of an induced circuit wave of contraction the difference in the amounts of CO_2 produced is somewhat smaller than in the former experiment although the rate of pulsation in the activated half-disk is on the average 3.143 times as great as that of a half-disk pulsating under the control of its sense organs. It seems to be clearly established from this type of experiment that there is some other form of metabolic activity which is of greater importance as a source of CO_2 and which is more directly under the influence of the rhopalia than is the activity of the muscular system.

In the comparison of normally pulsating half-disks and those activated by a circuit wave of contraction a series of cuts, equal in extent to those used in forming the labyrinth in activated specimens, were made in the tissues of the half disks with sense organs in order to guard against any inaccuracy in the results due to inequality in the extent of the laceration of the tissues. The activity of the muscular tissue—rate of pulsation—was 3.143 times as great in the half-disk containing the circuit wave of contraction as in the normally contracting specimen, but after various periods of from 5 to 15 hours, when the titrations were made it was found that in every experiment except one the greater amount of CO_2 had been produced by the half disk on which the sense-organs remained. In the single experiment which proved an exception to the regular result the excess of CO_2 in favor of the activated specimen were very slight in comparison to the difference in rate of pulsation which for this specimen was 28 per minute for the half-disk with rhopalia and 118 per minute for the activated half-disk.

HERITABLE VARIATIONS AND THE RESULTS OF SELECTION IN THE FISSION RATE OF STYLONYCHIA PUSTULATA

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Presented to the Academy, November 4, 1915

In organisms in which an admixture of two parents occurs at reproduction, the problems of evolutionary change become most complex and difficult. Heritable changes appear abundantly, but most of these are shown to be the definite working out of the numerical rules of inheritance. Whether any of the heritable changes that occur are of a different character is in dispute. In reproduction from a single parent these difficulties disappear; if evolutionary changes occur independent of biparental admixture it should be possible to demonstrate this in uniparental reproduction. Yet most recent work agrees that in such uni-